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The following information is taken from the documents submitted by the applicant.

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(54) Micromechanical optical switch

(57) The invention relates to a micromechanical optical switch.

In contrast to known solutions, data in the form of optical signals can easily be switched bidirectionally not only from 1-to-1 but also from 1-to-n, n-to-1 or n-to-n with one and the same arrangement. Furthermore, the embodiment in micromechanical design allows for a small construction with very short switching times and therefore high switching frequencies. For this purpose, a first and at least a second device influencing the light beam are arranged, each in a plane, one on top of the other between two cover plates. One of the devices influencing the light beam consists of at least one pivoted flat mirror. Between them in the region of the mirror is an optically free passage. Optical fibers are placed in grooves on the edges.

Description

The invention relates to a micromechanical optical switch.

Optical switches can be found in the state of the art, for example, in the documents, DE OS 37 42 553 on a light- and, in particular, laser-beam device and method as well as laser-workplace systems and DE OS 40 29 569 on a fiber-optical switch.

These arrangements, however, represent only 1-to-n couplings.

EP 0 153 243 also includes a switch for optical fibers. In this case, an optical element, which is positioned in the beam path between the ends of the optical fiber and the mirror, is moved along a linear path in such a way that the light beam is redirected in the optical element, reflected by the mirror and redirected a second time in the optical element and the light beam is thereby guided to the next optical fiber.

Disadvantages of this arrangement are, first of all, the moving optic and, secondly, that optical fibers can only be connected at a specified separation from one another. A free choice of the form 1-out-of-n is not possible.

Optical switches are described in the publications, DE OS 36 08 135, DE OS 37 16 836, DE OS 40 40 001 and DE OS 42 21 918. In these, various movable mirrors are employed as on/off switches for a fixed ordering of optical fibers. A freely selectable ordering from a number of optical fibers is not possible.

The invention presented in Claim 1 is based on the problem of bidirectionally distributing, mixing, separating and/or switching optical information with a micromechanical component.

This problem is solved with the characteristics listed in Claim 1.

The advantages attained with the invention consist particularly in that the data of optical signals can easily be switched bidirectionally not only from 1-to-1 but also from 1-to-n, n-to-1 or n-to-n with one and the same arrangement. The embodiment in micromechanical design allows the small construction with very short switching times and therefore high switching frequencies.

The layered construction facilitates an economical construction since the individual layers can be produced as functional planes using preparation technologies primarily known from microelectronics.

The layered structure for the optical arrangements that influence the light beam enables a universal construction according to the requirements set for the component. In this way, bidirectional switching structures of the form 1-to-1, 1-to-n, n-to-1 or n-to-n can be realized with one and the same device. The pivoted flat mirror or mirrors are realized as electrodes so, with appropriately designed counter-electrodes placed on the cover plates and an appropriate control unit, a tilting is realized. An additional drive mechanism for the pivoted flat mirror or mirrors is not needed.

Advantageous embodiments of the invention are given in the Claims 2 through 11.

The alternate embodiment of Claim 2 comprises a simple construction of the micromechanical optical switch with the switching possibilities, 1-to-n, n-to-1 or n-to-n, with n equaling the number of attached optical fibers. In addition, this solution has low optical losses for the light beam in transmission. If several such micromechanical optical switches are arranged in a plane, the result is a compact construction of several micromechanical optical switches that can be driven individually or in conjunction via optical interconnections.

The alternate embodiment of Claim 3 guarantees a uniform separation of the optical fibers from the prism.

A simple and economical construction using known and mature technologies of microelectronics is carried out in the alternate embodiments of Claims 4 through 6. The pivoted flat mirrors can be arranged not only as a $p \times p$ matrix but also in an arbitrary $p \times q$ ratio to one another, where p and q are the number of pivoted flat mirrors per side of the micromechanical optical switch. The number of pivoted flat mirrors thereby determines the switching ratio, 1-to-1, 1-to-n, n-to-1 or n-to-n, with n being equal to the number of optical fibers coupled with the micromechanical optical switch.

Micromechanical switches of a construction such as this are easy to stack so that, by having one or more optical connection between the micromechanical optical switches below one another, the switching possibilities, 1-to-n, n-to-1 or n-to-n, can be essentially increased in respect to individually constructed micromechanical optical switches.

In positioning the pivot axis of the pivoted flat mirror in the symmetry axis of the optical fiber and thereby in the symmetry axis of the light beam, the result is a simple mounting of the planes arranged one under the other. As a result, with regard to the surfaces of the pivoted flat mirrors lying one on top of the other, not only do their centers align but also, when their dimensions are equal, they lie congruently above one another. The optical fibers on the edges of the optical switch can thereby be used both as

sending as well as receiving elements. Corrections in the position of the light beam to the individual optical fibers are not required. By the arrangement of more than two planes with pivoted flat mirrors, a symmetric redirection of the light beams to the cover plates is produced.

Furthermore, only three switching states of the pivoted flat mirrors are required, so that control is essentially simplified. The three switching states are characterized by the states of being tilted relative to one another or not tilted.

The ridges on the cover plates corresponding to the alternate embodiments of Claims 7 and 8, simplify the control of the pivoted flat mirrors.

A simple realization of the pivoted flat mirrors using known and mature technologies of microelectronics makes the alternate embodiments of Claims 9 and 10 possible.

With the alternate embodiment of Claim 11, the pivot space of the pivoted flat mirrors up to the cover plates is given automatically so that it is not necessary to provide additional spacing frames for free pivoting over an angular range of 0 to 45°. Assembly expenses are simultaneously reduced.

Two embodiments of the invention are presented in the figures and described in more detail in the following.

It shows:

Fig. 1 Micromechanical optical switch with a one-piece optic and a pivoted flat mirror,

Fig. 2 Top view of the micromechanical optical switch presented in Fig. 1,

Fig. 3 Switch with two planes and 3 x 3 pivoted flat mirrors per plane, and

Fig. 4 Explosion view of the arrangement in Fig. 3.

A first embodiment of the micromechanical optical switch (1) consists essentially of a one-piece optic (3), as the first device influencing the light beam, in the first plane and the pivoted flat mirror (6), as the second device influencing the light beam, positioned one on top of the other and between the two cover plates (2a and 2b) (representations of Fig. 1 and 2).

The one-piece optic (3) sits in a spacing frame (9). The light beam arrives at the one-piece optic (3) by way of two or more optical fibers (10) arranged in a plane. For this purpose, the optical fibers (10) are guided into grooves matching each other found in one of the cover plates (2a) and the spacing frame (9). The separation of the optical fibers (10) continuously decreases in the direction of the one-piece optic (3) and

terminates directly at the latter. This surface of the one-piece optic (3) is formed to be circular and arching outward toward the optical fibers (10). Through this measure, the ends of the optical fibers (10) have the same distance from the center of the one-piece optic (3).

This space itself contains, in the first place, a totally reflective prism (4) and, in the second place, a lens (5). The light beam, after exiting one of the optical fibers (10) strikes the totally reflecting prism (4) and is deflected off this at an angle of 90° in the direction of the second device influencing the light beam. In this direction, the surface of the one-piece optic (3) is a lens (5). The pivoted flat mirror (6) is positioned in the focal point of this lens (5). For this purpose, the spacing frame (9) has an opening as optical passage (12) from the first device influencing the light beams to the second device influencing the light beams.

The pivoted flat mirror (6) is suspended in a frame (8) surrounding it by two torsion bars positioned centrally on opposite edges. The frame (8) as well as the pivoted flat mirror is prepared from a silicon sheet. The pivoted flat mirror (6) and the torsion bars (7) are etched out from a sacrificial layer and the remaining region of the silicon sheet itself acts as the support for the pivoted flat mirror and furthermore acts as spacer from the cover plate (2b) so that the pivoted flat mirror (6) can pivot freely against the cover plate (2b).

The pivoted flat mirror (6) has an area of $3 \times 3 \text{ mm}^2$. The pivot axis of the pivoted flat mirror (6) thereby lies perpendicular to the symmetry axis of the arched surface of the one-piece optic (3) on which the optical fibers (10) terminate. With the swiveling of the pivoted flat mirror (6), the light beam striking it is directed through the lens (5) and the totally reflecting prism (4), e.g., to the optical fibers (10) next to that from which the light beam exited.

The pivoted flat mirror (6) itself constitutes an electrode. On the cover plates (2b) arranged parallel to the pivoted flat mirror (6), there are two counter-electrodes (11a and 11b). These are positioned in correspondence to the edges of the pivoted flat mirror (6) running parallel to the symmetry axis of the pivot axis. With such an arrangement, it can be electrostatically controlled so that it can be pivoted in accordance with the potential on the electrodes.

The electrodes, in the form of the pivoted flat mirrors (6) and the counter-electrodes (11a and 11b), are connected with appropriate contacts on the

micromechanical optical switch (1) by way of electrical leads, so that the micromechanical optical switch (1) can be electrically connected from the exterior.

The other ends of the optical fibers (10) are connected with optical sending and/or receiving devices.

A second embodiment of the micromechanical optical switch (1) characterizes itself in that the first and the second device influencing the light beam consists of pivoted flat mirrors (6) arranged in the form of a matrix (Fig. 3 and 4).

A matrix in this embodiment contains 3 by 3 pivoted flat mirrors (6). These are supported on a surrounding frame (9) and two parallel-running strips (13). Thereby, each three pivoted flat mirrors (6) are found in sequence between frame (8) and strip (13) or between two strips (13). The free space between the pivoted flat mirrors (6) serves, at the same time, for optical transmission. The distances between the pivoted flat mirrors are equal. The pivoted flat mirror itself is connected with the frame (8) or the strip (13) by torsion bars (7) centrally attached onto opposite edges. The size of a pivoted flat mirror (6) is $1.4 \times 1.4 \text{ mm}^2$ with a thickness of $30 \text{ }\mu\text{m}$. The entire matrix is part of a silicon sheet, where the pivoted flat mirrors (6) including the torsion bars (7) represent part of a sacrificial layer and are etched out. The part of the silicon sheet surrounding the pivoted flat mirrors (6) represents the frame (8) and the strips (13) and simultaneously form part of the spacing frame (9).

Two matrices constructed in this way are arranged with an additional spacing frame (9) positioned between them in such a way that the symmetry lines of the pivot axes of the pivoted flat mirrors (6) are orthogonal to one another and each two pivoted flat mirrors (6) lie congruently facing one another.

Further spacing frames are found between the combined matrices and each of the cover plates (2a and 2b) over the pivoted flat mirrors (6). The spacing frames can be eliminated if the cover plates (2a and 2b) have appropriate recesses so that the pivoted flat mirrors can be freely pivoted from 0 to at least 45° . The frames or the cover plates (2a and 2b) have grooves arranged in accordance with one another in which the ends of the optical fibers (10) with attached graded-index lenses are placed.

The symmetry axes of the optical fibers (10) are perpendicular to the symmetry axes of the pivot axes of the pivoted flat mirrors (6), which are, furthermore, placed along the symmetry axes of the optical fibers (10). The light beam has a diameter of 0.8 to 1.0 mm and the pivoted flat mirror is $30 \text{ }\mu\text{m}$ thick, so that, if the light beam passes through

when the pivoted flat mirror (6) has not been swiveled, its thickness is insignificant. This reduction of the light beam is altogether negligible.

With a construction of the matrix of this kind, three optical fibers (10) can be connected on each side and therefore twelve optical fibers (10) altogether can be connected on the micromechanical optical switch (1) and can thereby be switched, mixed or separated.

The other ends of the optical fibers (10) are connected with optical sending and/or receiving devices.

The pivoted flat mirrors (6) are realized as electrodes. On the cover plates (2a and 2b) are found two counter-electrodes (11a and 11b) per pivoted flat mirror (6). These are positioned in correspondence to the edges of the pivoted flat mirror (6) running parallel to the symmetry axis of the pivot axis. With such an arrangement, they can be electrostatically controlled so that the pivoted flat mirrors (6) can be pivoted in accordance with the potential on the electrodes.

The electrodes, in the form of the pivoted flat mirrors (6) and the counter-electrodes (11a and 11b), are connected with appropriate contacts on the micromechanical optical switch (1) by way of electrical leads, so that the micromechanical optical switch (1) can be electrically connected from the exterior.

Claims

1. Micromechanical optical switch, characterized in that a first and at least a second device influencing light beams are arranged, each in a plane one on top of the other, between two cover plates (2a and 2b), that the second device influencing light beams is a pivoted flat mirror (6), that there is a spacing frame between the first and the second device influencing light beams, that, between the first and the second device influencing light beams in the region leading to the one or more pivoted flat mirror (6), there are an equal number of optically free passages (12), that grooves are made in the cover plates (2a and 2b), in the spacing frames (9) and/or in the planes of the first and second devices influencing laser beams in such a way that optical fibers are placed in them, that the pivoted flat mirrors (6) are realized as electrodes and that there are at least two electrodes (11a and 11b) arranged parallel to the mirror edges on the [cover plates (2a and 2b)] parallel to the pivoted flat mirrors (6).

2. Micromechanical optical switch according to Claim 1, characterized in that the first device influencing light beams is at least one one-piece optic (3) in the form of a prism (4) with integrated lens (5), that at least two ends of the optical fibers (10) guided along the grooves terminate on the one-piece optic (3), that the lens (5) is positioned orthogonal to the optical fibers (10) and to the second device influencing light beams, that the second device influencing light beams in the form of the pivoted flat mirror (6) is positioned in the beam path so that the pivot axis is located in the symmetry axis of the optical fiber (10), that the pivoted flat mirror represents an electrode and that, for each edge of the pivoted flat mirrors parallel to the symmetry axes of the pivot axes, there is a counter-electrode (11a and 11b) running parallel to it on the cover plate (2b) oriented parallel to the mirrors.
3. Micromechanical optical switch according to Claim 2, characterized in that a one-piece optic is formed arching outward toward the optical fibers and that the relative separation of the grooves from the one-piece optic continuously decreases.
4. Micromechanical optical switch according to Claim 1, characterized in that the first device influencing light beams consists of at least one arrangement for which a pivoted flat mirror (6) is positioned between two opposing ends of light-guiding devices in such a way that the symmetry axes of the light beams and the pivot axis of the pivoted flat mirror (6) are coplanar, that the second device influencing light beams is at least one similar arrangement, that, relative to the former, the latter is positioned under rotation of 90° in the plane so that the centerpoint of the pivoted flat mirrors (6) in one symmetry axis and the unrotated pivoted flat mirrors are parallel to each other, that the light-guiding devices on the edges in the form of optical fibers (10) are connected with sending and/or receiving devices by way of graded-index lenses (14), that there are spacing frames (9) between the first and the second devices influencing light beams, that the first and the second device influencing light beams are between two cover plates (2a and 2b), that the pivoted flat mirrors represent electrodes, that, for each edge of the pivoted flat mirrors parallel to the symmetry axes of the pivot axes, a counter-electrode (11a and 11b) is positioned running parallel to it on the cover plate (2a and 2b) oriented parallel to the mirrors and that the spacing frames and the cover plates (2a and 2b) contain grooves for the light-guiding devices.
5. Micromechanical optical switch according to Claim 4, characterized in that several arrangements, in which a flat mirror that can pivot on an axis running

perpendicular to the beam path is positioned between two opposing ends of the light-guiding devices in such a way that the symmetry axis of the light beam and the pivot axis of the pivoted flat mirror (6) are coplanar, are arranged in series and parallel and that on the edges there are optical fibers (10) optically connected via graded-index lenses (14) with sending and/or receiving devices.

6. Micromechanical optical switch according to Claim 4, characterized in that there are the same number of arrangements, in which a flat mirror that can pivot on an axis running perpendicular to the beam path is positioned between two opposing ends of the light-guiding devices in such a way that the symmetry axis of the light beam and the pivot axis of the pivoted flat mirror (6) are coplanar, as first and second devices influencing light beams and that on the edges there are optical fibers (10) optically connected via graded-index lenses (14) with sending and/or receiving devices.

7. Micromechanical optical switch according to Claim 4, characterized in that spacers are located on the cover plates (2a and 2b) corresponding to the edges of the pivoted flat mirrors running parallel to the pivot axis.

8. Micromechanical optical switch according to Claim 7, characterized in that the height of the spacers is equal to the separation of the edges parallel to the pivot axis of the pivoted flat mirrors (6) in the state of being tilted at an angle of 45° relative to the cover plates (2a and 2b) and the [plane of the] cover plates (2a and 2b).

9. Micromechanical optical switch according to Claims 1 through 6, characterized in that the pivoted flat mirror (6) is connected with a frame (8) surrounding the pivoted flat mirror by way of two torsion bars (7) centrally positioned on opposite edges or that the pivoted flat mirror (6) is connected with parallel oriented strips (13) by way of two torsion bars (7) centrally positioned on opposite edges.

10. Micromechanical optical switch according to Claim 9, characterized in that the pivoted flat mirror or mirrors (6), the torsion bars (7), the frame (8) and the parallel oriented strips (13) is a semiconductor sheet provided and structured with layers.

11. Micromechanical optical switch according to Claim 10, characterized in that the frame is a sacrificial layer of the semiconductor sheet and that the pivoted flat mirror or mirrors and the torsion bars (7) are part of the sacrificial layer.

3 page(s) of figures are appended
